

PTO 09-4221

CC=JP DATE=19981208 KIND=A  
PN=10326607

BATTERY SEPARATOR AND MANUFACTURING METHOD THEREFOR  
[Denchiyo separeta oyobi sono seizo hoho]

Yoshinobu Omae, et al.

UNITED STATES PATENT AND TRADEMARK OFFICE  
Washington, D.C. April 2009

Translated by: FLS, Inc.

PUBLICATION COUNTRY	(19):	JP
DOCUMENT NUMBER	(11):	10326607
DOCUMENT KIND	(12):	A
	(13):	
PUBLICATION DATE	(43):	19981208
PUBLICATION DATE	(45):	
APPLICATION NUMBER	(21):	09135064
APPLICATION DATE	(22):	19970526
ADDITION TO	(61):	
INTERNATIONAL CLASSIFICATION	(51):	H01M 2/16, D04H 1/58, H01M 10/24
DOMESTIC CLASSIFICATION	(52):	
PRIORITY COUNTRY	(33):	
PRIORITY DATE	(32):	
PRIORITY NUMBER	(31):	
INVENTORS	(72):	OMAE, YOSHINOBU; SONEDAKA, TOMOYASU; NAGI, HISASHI; EZAKI, TAMEMARU.
APPLICANT	(71):	KURARAY CO LTD
TITLE	(54):	BATTERY SEPARATOR AND MANUFACTURING METHOD THEREFOR
FOREIGN TITLE	[54A]:	DENCHIYO SEPARATA OYOBI SONO SEIZO HOHO

[Claims]

[Claim 1] A battery separator comprising a non-woven cloth whose main fibers are polypropylene fibers sulfonated to a sulfur concentration of 10,000 ppm and having a weight average molecular weight of 80,000 to 150,000 and a monofiber fineness of 0.01 to 0.1 deniers, the maximum pore diameter for the pore size of the non-woven cloth being 25 to 150  $\mu\text{m}$ .

[Claim 2] A method for the manufacture of a battery separator, wherein a cloth weave or random weave of mixed fibers is entwined and then sulfonated, and wherein the mixed fibers comprise olefin-based binder fibers and sea-island compound fibers in which the sea component is a polyamide resin with a number average molecular weight of 10,000 to 20,000 and in which the island component is a polypropylene with a weight average molecular weight of 80,000 to 150,000.

[Detailed Description of the Invention]

[0001] [Technical Field of the Invention]

The present invention relates to a battery separator and to a manufacturing method for this battery separator, which is ideal for use in alkali rechargeable batteries such as nickel-cadmium batteries, nickel-zinc batteries and nickel-hydrogen batteries.

[0002] [Prior Art]

The separator in an alkali rechargeable battery is usually a non-woven cloth manufactured using the dry method or the wet method. It

---

\* Claim and paragraph numbers correspond to those in the foreign text.

often consists of hydrophilic polyamide fibers and polyolefin fibers with superior alkali resistance and acid resistance. Polyamide fibers are very alkali resistant at room temperature. However, their durability decreases at temperatures above 80°C due to hydrolysis. The hydrolytes dissolve in the electrolyte, and battery performance deteriorates significantly. A surfactant is applied to the polyolefin fibers and then a hydrophilic treatment is performed such as sulfonation treatment, plasma treatment or sputter etching treatment.

[0003] In recent years, rechargeable alkali batteries have become as small as dry cell batteries. These compact, high-capacity batteries are used in compact, light-weight electronic devices. To meet these demands, the electrolyte retention of the separator has to be increased and the separator itself has had to become thinner. In order to overcome these problems, the substrate has had to become less dense. The through-holes have become larger depthwise with less density, and this has decreased dendrite durability and decreased strength. These make battery production more difficult. Dendrites are the phenomenon of metal ions dissolved in the electrolyte during discharges growing in a needle shape on the surfaces of the metal electrodes during charging. These make overcharging more likely. A polyolefin fiber paper has been proposed in Kokai No. 8-35192 containing at least 40 wt% hydrophilic polyolefin fibers. This weighs 15 g/m<sup>2</sup> to 100 g/m<sup>2</sup> and the density is 0.2 g/cm<sup>3</sup> to 0.5 g/cm<sup>3</sup>. While thin enough to provide sufficient solution retention, the strength is insufficient, and the

shut-down function is not a sufficient safety countermeasure when the battery gets extremely hot during charging and discharging.

[0004] [Problems(s) Solved By the Invention]

The purpose of the present invention is to solve the problem associated with the prior art by providing a battery separator and a manufacturing method for this battery separator, which is very strong despite being thin, and has a shut-down function as well as superior solution retention and solution absorption properties.

[0005] [Means of Solving the Problem(s)]

As a result of extensive research in light of this problem, the present inventors were able to solve the problem with a non-woven cloth of a predetermined pore size using ultra fine 0.01 to 0.1 denier polypropylene fibers. The present invention is a product of this solution.

[0006] In other words, the present invention is a battery separator comprising a non-woven cloth whose main fibers are polypropylene fibers sulfonated to a sulfur concentration of 10,000 ppm and having a weight average molecular weight of 80,000 to 150,000 and a monofiber fineness of 0.01 to 0.1 deniers, the maximum pore diameter for the pore size of the non-woven cloth being 25 to 150  $\mu\text{m}$ . The present invention is also a method for the manufacture of a battery separator, wherein a cloth weave or random weave of mixed fibers is entwined and then sulfonated, and wherein the mixed fibers comprise olefin-based binder fibers and sea-island compound fibers in which the sea component is a polyamide resin with a number average

molecular weight of 10,000 to 20,000 and in which the island component is a polypropylene with a weight average molecular weight of 80,000 to 150,000.

[0007] [Embodiment of the Invention]

The following is a detailed explanation of the present invention. The polypropylene resin used in the present invention has a weight average molecular weight of 80,000 to 150,000, preferably 100,000 to 120,000. If the weight average molecular weight of the polypropylene resin is less than 80,000, the spinnability is poor during the spinning and spinning twist, and the spinning is not good. If the weight average molecular weight of the polypropylene resin is greater than 150,000, the viscosity is too high during the melting process, the tube pressure loss is too high for the polypropylene polymer during the spinning process, and the discharge pressure is too high. As a result, spinning cannot be performed.

[0008] The monofilament fineness of the polypropylene fibers is between 0.01 to 0.1 deniers, and preferably between 0.04 and 0.08 deniers. If the monofilament fineness of the polypropylene fibers is less than 0.01 deniers, the maximum pore diameter for the pore size of the unwoven cloth described below is less than 25  $\mu\text{m}$ . This causes a decrease in permeability and a rise in electrical resistance when the thickness is set to obtain the target strength for a battery separator. If the monofilament fineness of the polypropylene fibers is greater than 0.1 deniers, the maximum pore diameter for the pore size of the unwoven cloth described below is greater than 150  $\mu\text{m}$ . While this has

advantages such as improved solution retention and lower electrical resistance, it causes a loss of the shut-down function which is a safety countermeasure for an abnormal rise in battery temperature during the charging and discharging process.

[0009] The sulfur concentration in the ultra fine polypropylene fibers due to sulfonation is 10,000 ppm or less, preferably between 10 and 8,000 ppm. Sulfonation is a means of providing poorly hydrophilic polyolefin fibers with hydrophilic properties. The sulfur concentration is used as an alternate value for the degree of sulfonation. If the sulfur concentration is less than 10 ppm, the hydrophilic properties are poor and the desired battery separator is difficult to obtain. If the sulfur concentration is greater than 10,000 ppm, sufficient hydrophilic properties can be provided. However, the immersion time in the sulfonation solution to achieve this is too long and these conditions are not desirable from an industrial perspective.

[0010] The maximum diameter for the pore size of the unwoven cloth whose main component is a sulfonated polypropylene ultra fine fiber is between 25  $\mu\text{m}$  and 150  $\mu\text{m}$ , preferably between 40  $\mu\text{m}$  and 120  $\mu\text{m}$ , and ideally between 40  $\mu\text{m}$  and 100  $\mu\text{m}$ . This pore size is an alternative characteristic for permeability, electrical resistance and the shut down function which, in turn, are essential characteristics of a battery separator.

[0011] The present inventors conducted extensive research to obtain a 0.01 to 0.1 denier polypropylene fiber. As a result, they

determined that a sea-island fiber using a polyamide resin with a number average molecular weight of 10,000 to 20,000 for the sea component and a polypropylene resin with a weight average molecular weight of 80,000 to 150,000 for the island component was ideal. 0.01 to 0.1 denier polypropylene fibers are obtained because polypropylene fibers greater than 1 denier are very difficult to obtain safely under industrial conditions. Thus, there is a limit of 0.5 deniers for the monofilament fineness of the polypropylene fibers after the sheath component has been removed, even when polypropylene is used as the core component in a sheath-and-core structure. If the number average molecular weight of the polyamide resin used in the sea component of the sea-island fibers is less than 10,000, the polymer viscosity decreases and spinnability deteriorates significantly. As a result, it is unsuitable as a fiber spinning resin. If the number average molecular weight is greater than 20,000, the viscosity is too high when melted. This causes problems that make spinning impossible, such as high tube pressure loss and high discharge pressure for the polyamide polymer during spinning.

[0012] Any polyamide can be used as long as it can be melted and removed during immersion in the sulfonation solution. Typical examples are nylon resins such as nylon 6, nylon 66, nylon 10, nylon 12 and nylon copolymers.

[0013] The following is an explanation of the polyolefin binder fibers. The structure of the olefin-based binder resins in the present invention are simply polymer fibers or compound fibers of two or more



polymers such as sheath-and-core, side-by-side, layered split and radial split compound fibers. The cloth-sectional shape can be round, flat, cocoon, hollow and T-shaped. There are no particular restrictions. The monofilament fineness is preferably 0.5 to 5 deniers. If less than 0.5 deniers, the spinnability is poor. If more than 5 deniers, a non-woven cloth with the desired pore size cannot be obtained.

[0014] Examples of polyolefins include ethylene, propylene, 1-butene, 1-hexene, 3-methyl-1-butene, 3-methyl-1-pentene, 4-methyl-1-pentene, 3,3-dimethyl-1-butene, 4,4-dimethyl-1-pentene, 3-methyl-1-hexene, 4-methyl-1-hexene, 4,4-dimethyl-1-hexene, 5-methyl-1-hexene, allylcyclopentane, allylcyclohexane, allylbenzene, 3-cyclohexyl-1-butene, vinylcyclopropane, vinylcyclohexane, 2-vinylbicyclo[2,2,1]-pentane, other polymers, and copolymers of these. Preferred polymers for the polyolefin binder fibers in the complex fibers include ethylene, propylene, 1-butene, 1-hexene, 3-methyl-1-butene, 3-methyl-1-pentene, 4-methyl-1-pentene, 3,3-dimethyl-1-butene, 4,4-dimethyl-1-pentene, and 3-methyl-1-hexene. Copolymers of these can also be used. Core-and-sheath compound fibers of ethylene and propylene are especially preferred.

[0015] Next, the manufacturing method for the battery separator will be explained in detail. A cloth weave or random weave is manufactured using a roller card, cloth wrapper or random weaver from the sea-island fibers and polyolefin binder fibers described above. Afterwards, they are entwined using a needle punch or water entwining.

If the entwining is performed using a needle punch, the diameter of the needle should be thick enough to obtain a pore size large enough for a battery separator. In the water entwining, a nozzle plate with one to three rows, a nozzle diameter of 0.03 mm to 0.3 mm, preferably 0.9 mm to 0.2 mm, and a pitch of 0.15 mm to 5 mm, preferably 0.5 mm to 1.5 mm, should be used. The water jet can be performed one or more times at a water pressure of 10 to 500 kg/cm<sup>2</sup>. Next, heat treatment is performed at a temperature corresponding to the melting point of the binder component in the polyolefin binder fibers. The weave is then immersed in a sulfonation solution and sulfonation is performed. The sulfonation solution used here can be fuming sulfuric acid, sulfuric acid, chromic acid and nitric acid. Fuming sulfuric acid is preferred because it has high reactivity and it makes sulfonation relatively easy. After sulfonation, the unwoven fabric is ideally rinsed with the diluted sulfonation solution and then water, followed by drying. If necessary, a surfactant can be added to improve the hydrophilic properties and a polyolefin film can be applied to provide more strength.

[0016] [Working Example(s)]

The following is a more detailed explanation of the present invention with reference to working examples. The present invention is by no means limited to these working examples.

[0017] The weight average molecular weight and number average molecular weight of the resins were measured using the GPC method. The pore size was measured using a Colter Porometer II from Colter

Electronics Ltd. An absorption solution in which sulfonated fibers have been absorbed using the oxygen combustion flask method is analyzed using the Ion Chromatoanalyzer by Yokogawa Electric Co. Ltd. to determine the sulfur concentration introduced during sulfonation.

[0018] The physical properties of the battery separator were evaluated using the following method. The weight was measured in accordance with JIS P 8124 'Paper Weight GSM Measuring Method'. The thickness and density were measured in accordance with JIS P 8118 'Thickness and Density Measurement Methods for Paper and Cardboard'. The breaking length was measured in accordance with JIS P 8113 'Paper and Cardboard Tensile Strength Testing Methods'. In the absorption solution, 35% KOH was used as the processing solution, and the amount of remaining solution was measured after 30 second separation of the natural solution using a 50 mm x 50 mm sample. As for the absorption solution rate, 35% KOH was used as the processing solution, and the 25 mm suction time was measured. The permeation was measured in accordance with the permeation measurement method in JIS L 1096-1990 'General Textile Testing Methods' using a Brazil-type permeation tester manufactured by Toyo Seiki Seisakusho, Ltd.

[0019] Working Example 1

4.3 denier sea-island type compound fibers (sea-island ratio = 40:60, 50 islands) were spun with nylon 6 (number average molecular weight: 13,000) sea components and polypropylene (weight average molecular weight: 105,200) island components to obtain the main fibers (monofilament fineness in the island components: 0.052 deniers). 2.1

denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this manner was sulfonated with fuming sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had superior solution retention and water absorption properties. In a short circuit simulation test, an alternating current load was applied to an AA-size spiral-type battery using lithium foil electrodes. The battery current and canister temperature were then measured to evaluate the shut-down performance. The results were good.

[0020] [Table 1]

Table 1

	WE 1	WE 2	WE 3	WE 4	CE 3	CE 4	CE 5	CE 6
Thickness (mm)	0.11	0.14	0.08	0.16	0.15	0.07	0.18	0.15
Weight (g/m <sup>2</sup> )	50	50	40	40	50	40	70	55
Density (g/cm <sup>3</sup> )	0.45	0.36	0.50	0.27	0.33	0.57	0.39	0.37
Breaking Length (Km)	5.76	5.39	8.62	7.46	5.03	8.79	2.83	8.42
Elongation (%)	17.5	20.2	14.3	23.8	19.1	12.2	30.9	13.2
Max. Pore Size (m)	75	144	31	127	163	18	351	176
Sulfur Conc. (ppm)	800	7000	45	750	4550	2300	5300	-
Permeability (cm <sup>3</sup> /cm <sup>2</sup> /sec)	4.5	6.6	1.1	4.9	7.1	0.2	19.8	0.1
Absorption (g/g)	5.96	8.32	3.75	6.51	7.76	3.11	2.15	0.70
Absorption Rate (sec/25 mm)	55	68	28	50	106	89	675	1800 <
Shut Down Function	O	O	O	O	Δ	-	-	-

[0021] Working Example 2

9.8 denier sea-island type compound fibers (sea-island ratio = 50:50, 50 islands) were spun with nylon 6 (number average molecular weight: 18,000) sea components and polypropylene (weight average molecular weight: 140,000) island components to obtain the main fibers (monofilament fineness in the island components: 0.098 deniers). 2.1 denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 50:50 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained

in this manner was sulfonated with fuming sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had superior solution retention and water absorption properties. In a short circuit simulation test, an alternating current load was applied to an AA-size spiral-type battery using lithium foil electrodes. The battery current and canister temperature were then measured to evaluate the shut-down performance. The results were good.

#### [0022] Working Example 3

2.7 denier sea-island type compound fibers (sea-island ratio = 60:40, 37 islands) were spun with nylon 6 (number average molecular weight: 11,000) sea components and polypropylene (weight average molecular weight: 95,000) island components to obtain the main fibers (monofilament fineness in the island components: 0.029 deniers). 2.1 denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 80:20 ratio, and a random weave was manufactured using a random weaver. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this

manner was sulfonated with fuming sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had superior solution retention and water absorption properties. In a short circuit simulation test, an alternating current load was applied to an AA-size spiral-type battery using lithium foil electrodes. The battery current and canister temperature were then measured to evaluate the shut-down performance. The results were good.

#### [0023] Working Example 4

4.0 denier sea-island type compound fibers (sea-island ratio = 40:60, 37 islands) were spun with nylon 6 (number average molecular weight: 13,000) sea components and polypropylene (weight average molecular weight: 105,200) island components to obtain the main fibers (monofilament fineness in the island components: 0.065 deniers). 2.2 denier side-by-side compound fibers were also spun as the binder fibers consisting of polyethylene and polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this manner was sulfonated with

80°C concentrated sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had superior solution retention and water absorption properties. In a short circuit simulation test, an alternating current load was applied to an AA-size spiral-type battery using lithium foil electrodes. The battery current and canister temperature were then measured to evaluate the shut-down performance. The results were good.

[0024] Comparative Example 1

Sea-island fibers were manufactured in the same manner as the first working example, except that nylon 6 with a number average molecular weight of 9,000 was used as the sea component and polypropylene with a weight average molecular weight of 72,000 was used as the island component. The spinnability was poor during the spinning process, and fibers could not be spun.

[0025] Comparative Example 2

Sea-island fibers were manufactured in the same manner as the first working example, except that nylon 6 with a number average molecular weight of 22,000 was used as the sea component and polypropylene with a weight average molecular weight of 153,000 was used as the island component. The discharge pressure was high in the spinning stage, and fibers could not be spun.

[0026] Comparative Example 3

7.0 denier sea-island type compound fibers (sea-island ratio = 40:60, 37 islands) were spun with nylon 6 (number average molecular



weight: 13,000) sea components and polypropylene (weight average molecular weight: 105,200) island components to obtain the main fibers (monofilament fineness in the island components: 0.114 deniers). 2.1 denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this manner was sulfonated with 80°C concentrated sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had a large pore size. In a short circuit simulation test, an alternating current load was applied to an AA-size spiral-type battery using lithium foil electrodes. The battery current and canister temperature were then measured to evaluate the shut-down performance. The results were not good and it was insufficient as a rechargeable battery separator.

[0027] Comparative Example 4

5.2 denier sea-island type compound fibers (sea-island ratio = 40:60, 400 islands) were spun with nylon 6 (number average molecular

weight: 11,000) sea components and polypropylene (weight average molecular weight: 95,000) island components to obtain the main fibers (monofilament fineness in the island components: 0.008 deniers). 2.1 denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this manner was sulfonated with 80°C concentrated sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was very strong despite being thin and had a small pore size. Permeation and solution retention were poor, and battery performance was not good.

#### [0028] Comparative Example 5

The main fibers were simple 1.1 denier polypropylene fibers, and the binder fibers were 2.1 denier sheath-core compound fibers in which the sheath component was polyethylene and the core component was polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio and a cloth weave was manufactured using a roller

card and a cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The sheet obtained in this manner was sulfonated with fuming sulfuric acid, rinsed with diluted sulfuric acid and water, and then dried to obtain the target battery separator. As shown in Table 1, the battery separator was thin and had a large pore size. Also, the breaking length was short and the strength was poor. As a result, it was insufficient as a separator for a rechargeable battery.

[0029] Comparative Example 6

Polypropylene with a weight average molecular weight of 127,000 and polyethylene were used to spin 3.1 denier radial split-type compound fibers (16 splits). (This fineness of the polypropylene monofibers was 0.097 deniers.) These were the main fibers. 2.1 denier sheath-core compound fibers were also spun as the binder fibers with the sheath component being polyethylene and the core component being polypropylene. The main fibers and binder fibers were mixed together at a 70:30 ratio, and a cloth weave was manufactured using a roller card and cloth wrapper. Afterwards, water treatment was performed once on the front and rear surfaces using a single-row nozzle plate with a nozzle diameter of 0.1 mm and a pitch of 0.6 mm. The water pressure of the stream was 30 kg/cm<sup>2</sup>-50 kg/cm<sup>2</sup>-80 kg/cm<sup>2</sup>-100 kg/cm<sup>2</sup>. Next, heat

treatment was performed at 150°C, 20 kg/cm (heat roller linear pressure) and a line rate of 1 m/min. The properties were evaluated as a battery separator (see Table 1). It was thin and strong, but the solution retention and solution absorption properties were poor. Thus, it was insufficient as a separator for a rechargeable battery.

[0030] [Effect(s) of the Invention]

The present invention is a battery separator comprising a non-woven cloth whose main fibers are polypropylene fibers sulfonated to a sulfur concentration of 10,000 ppm and having a weight average molecular weight of 80,000 to 150,000 spun to a monofiber fineness of 0.01 to 0.1 deniers, the maximum pore diameter for the pore size of the non-woven cloth being 25 to 150  $\mu\text{m}$ . As a result, a battery separator can be obtained that is very strong despite being very thin, and that has a shut-down function as well as superior solution retention and solution absorption. The present invention is also a method for the manufacture of a battery separator, wherein a cloth weave or random weave non-woven cloth of mixed fibers is entwined and then sulfonated by immersion in a sulfonation solution, and wherein the mixed fibers comprise olefin-based binder fibers and sea-island compound fibers in which the sea component is a polyamide resin with a number average molecular weight of 10,000 to 20,000 and in which the island component is a polypropylene with a weight average molecular weight of 80,000 to 150,000. Here the monofiber fineness of the polypropylene in the island component excluding the sea component is

0.01 to 0.1 deniers. This method can be used to obtain the target battery separator.